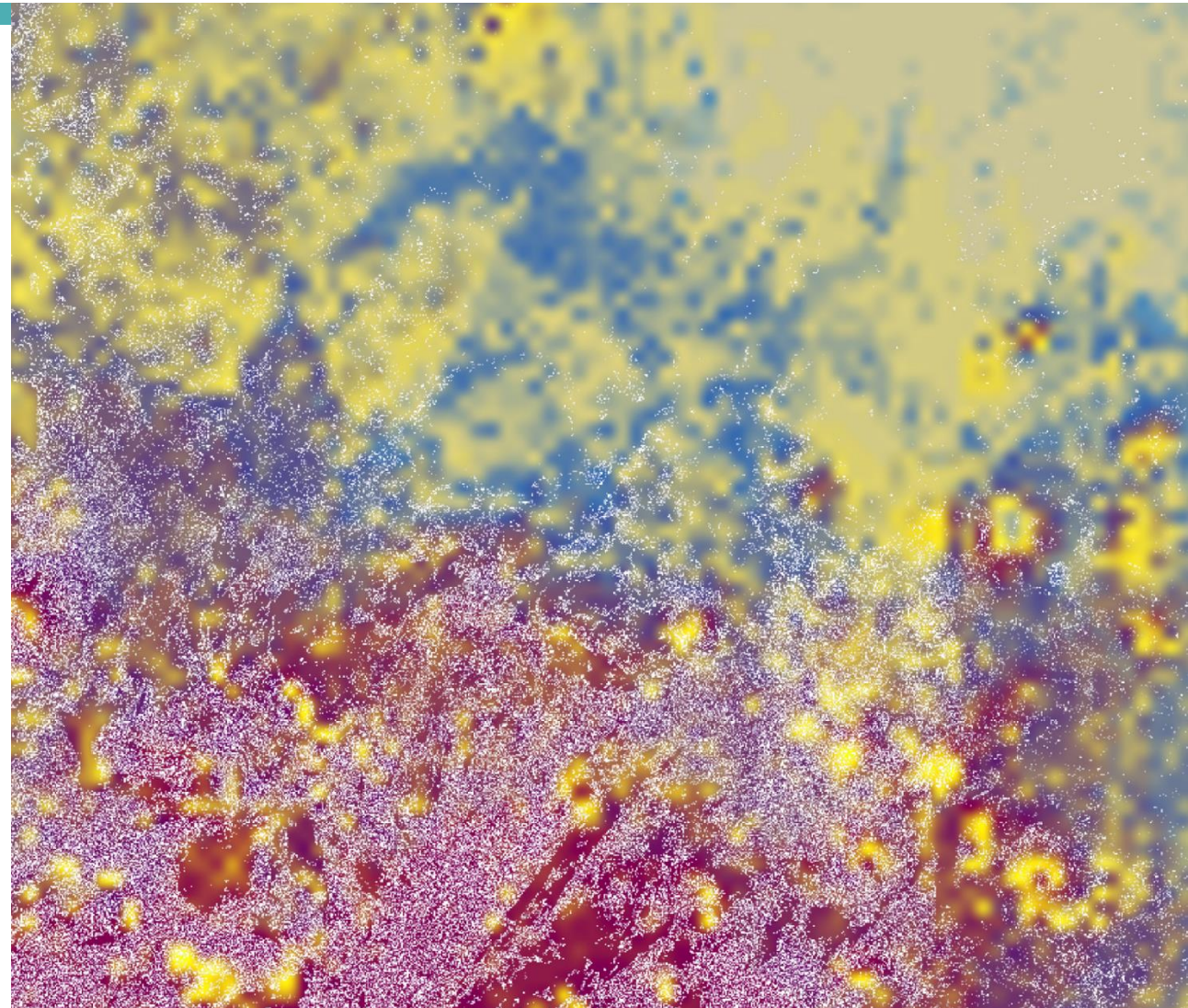# Arizona
Water Resources

Utilizing Aerial Imagery and NASA Earth Observations to Assess Pinyon-Juniper Tree Mortality in Flagstaff, AZ

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DEVELOP

PARTNERS

National Park Service, Flagstaff Area National Monuments

Wupatki National Monument

Mark Szydlo, Biologist

▸ Seeking to better understand pinyon-juniper tree mortality in 2021

▸ Limited use of remote sensing to monitor landscape-scale changes

Image Credit: NPS

STUDY AREA

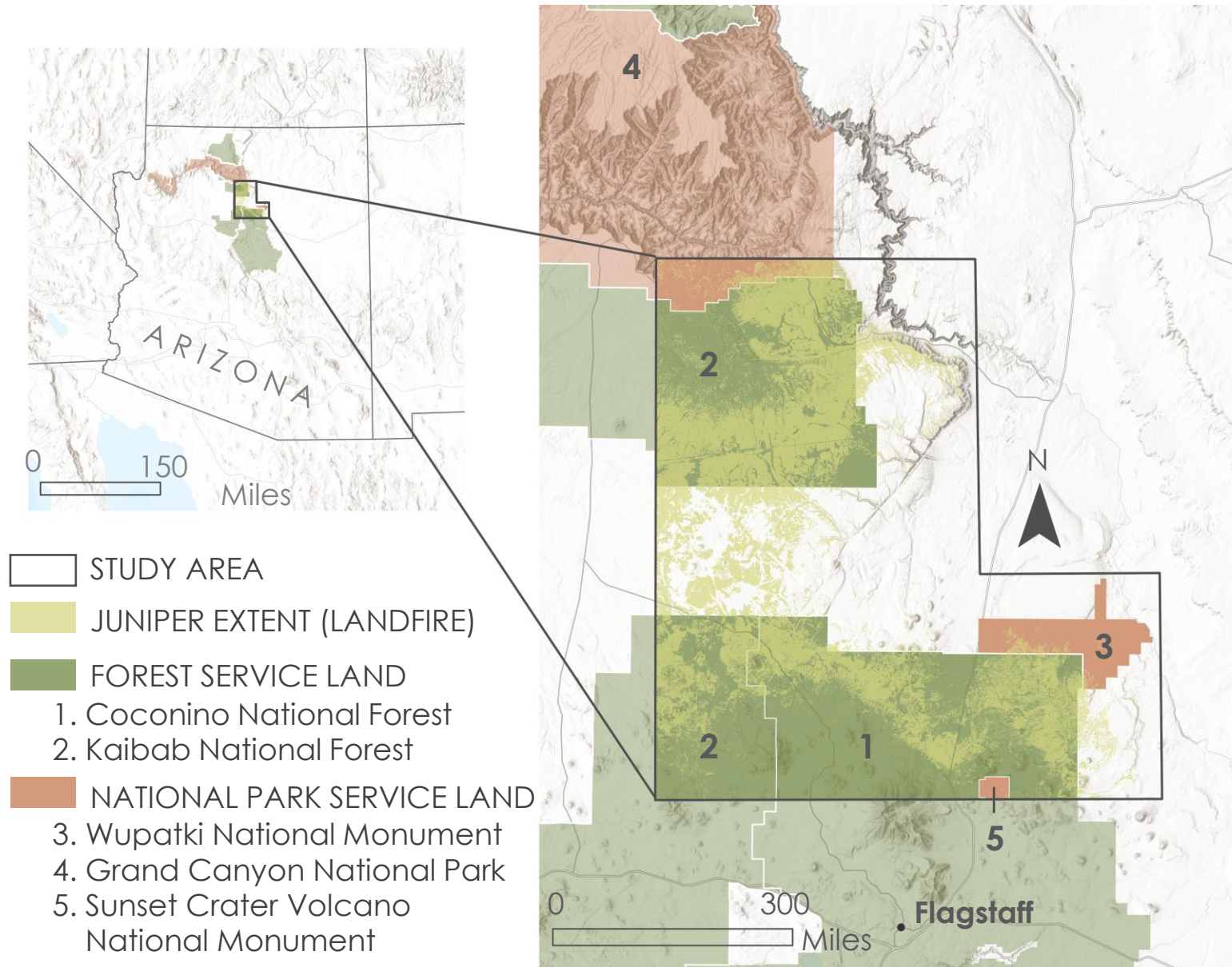▸ **1.9-million-acre** study area near Flagstaff, AZ

▸ Study period: **2015 – 2021**

Pinyon-juniper tree experiencing partial mortality.

Image Credit: Mark Szydlo

Map Legend

STUDY AREA

JUNIPER EXTENT (LANDFIRE)

FOREST SERVICE LAND
1. Coconino National Forest
2. Kaibab National Forest

NATIONAL PARK SERVICE LAND
3. Wupatki National Monument
4. Grand Canyon National Park
5. Sunset Crater Volcano National Monument

Image Credit: DEVELOP Team, Basemap: Esri, World Terrain Base

ARIZONA

0 150 Miles

Flagstaff

N

0 300 Miles

COMMUNITY CONCERNS

Increased wildfire risk to cultural resource sites

Prolonged drought resulting in regional hydrological and ecological shifts

Drought-related pinyon-juniper mortality across the landscape

Reduction of important habitat for wildlife

Image Credit: Mark Szydlo (left), Mark Szydlo (center), National Park Foundation (top right), Jane Shelby Richardson (bottom right)

PROJECT OBJECTIVES

Map and assess extent of pinyon-juniper tree mortality

Evaluate factors including evapotranspiration, climatic, and topographic variables using NASA Earth observation data

Provide partners with a method for continued monitoring and detection of mortality events

RESEARCH PROCESS

The WHERE
Ancillary Data

Map Pinyon-Juniper Mortality

The WHY
NASA Earth
Observations

Map Environmental Factors in
ArcGIS

Plot Time Series of Environmental
Factors in Tableau

Statistical Analyses of Mortality
and Environmental Factors in R

METHODOLOGY: NAIP IMAGERY

1. **Unsupervised classification** with NAIP imagery

2. **Accuracy assessments** of land cover classifications

3. **Re-classification** with only vegetated classes

4. Inter-year **differencing** and **mortality accuracy assessment**
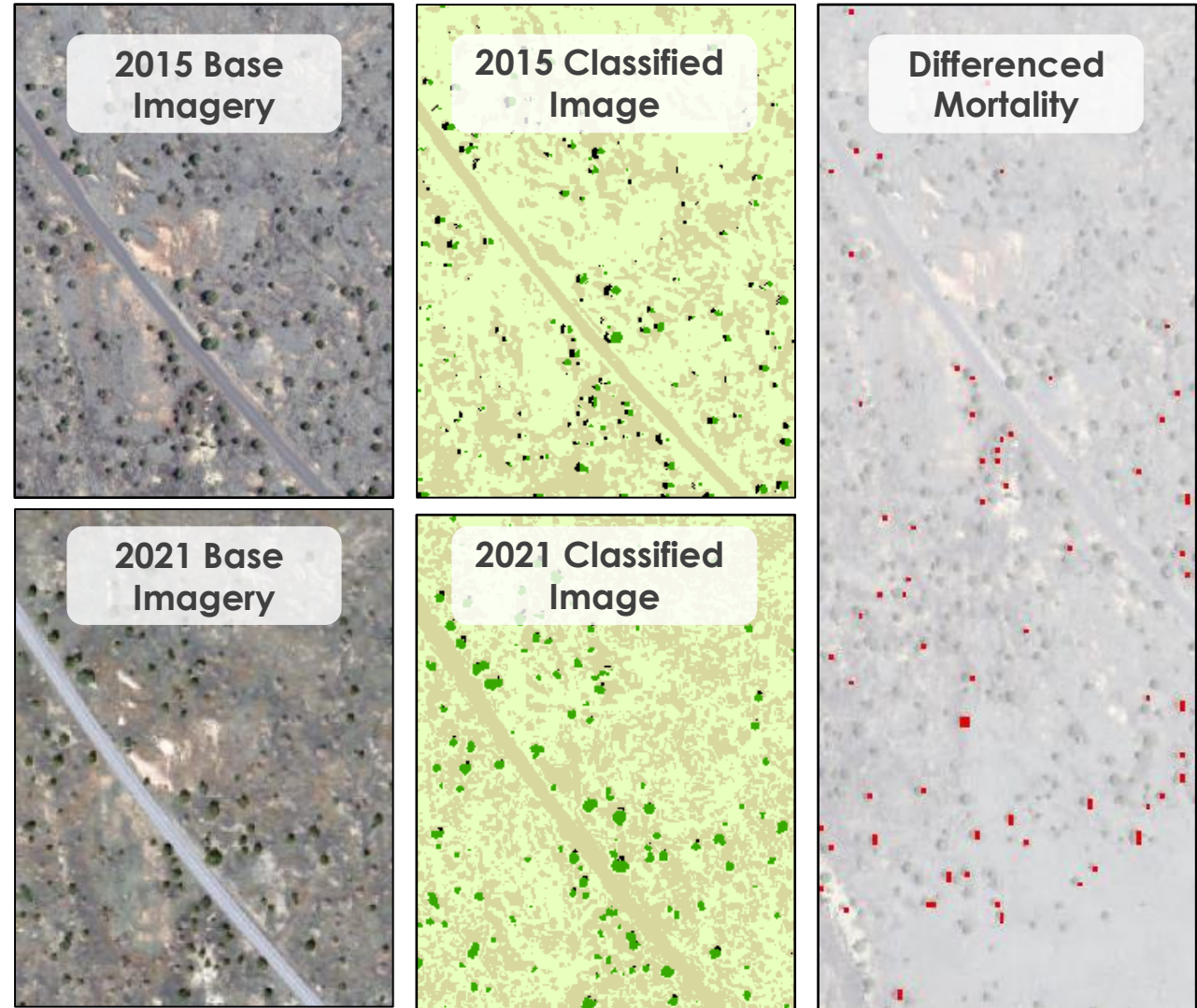
5. Percent mortality **calculations**

Image Credit: DEVELOP Team

RESULTS: ACCURACY ASSESSMENT

▶ **82% accuracy** for 2015 landcover classification

▶ **73% accuracy** for 2021 landcover classification

▶ **89% accuracy** for differenced mortality in high probability areas*

Image Credit: DEVELOP Team

*Areas excluding burn areas and mixed pinyon-juniper ponderosa forests

RESULTS: PINYON-JUNIPER MORTALITY

▶ **43% mortality** in high probability areas*

▶ **47% mortality** in Wupatki National Monument

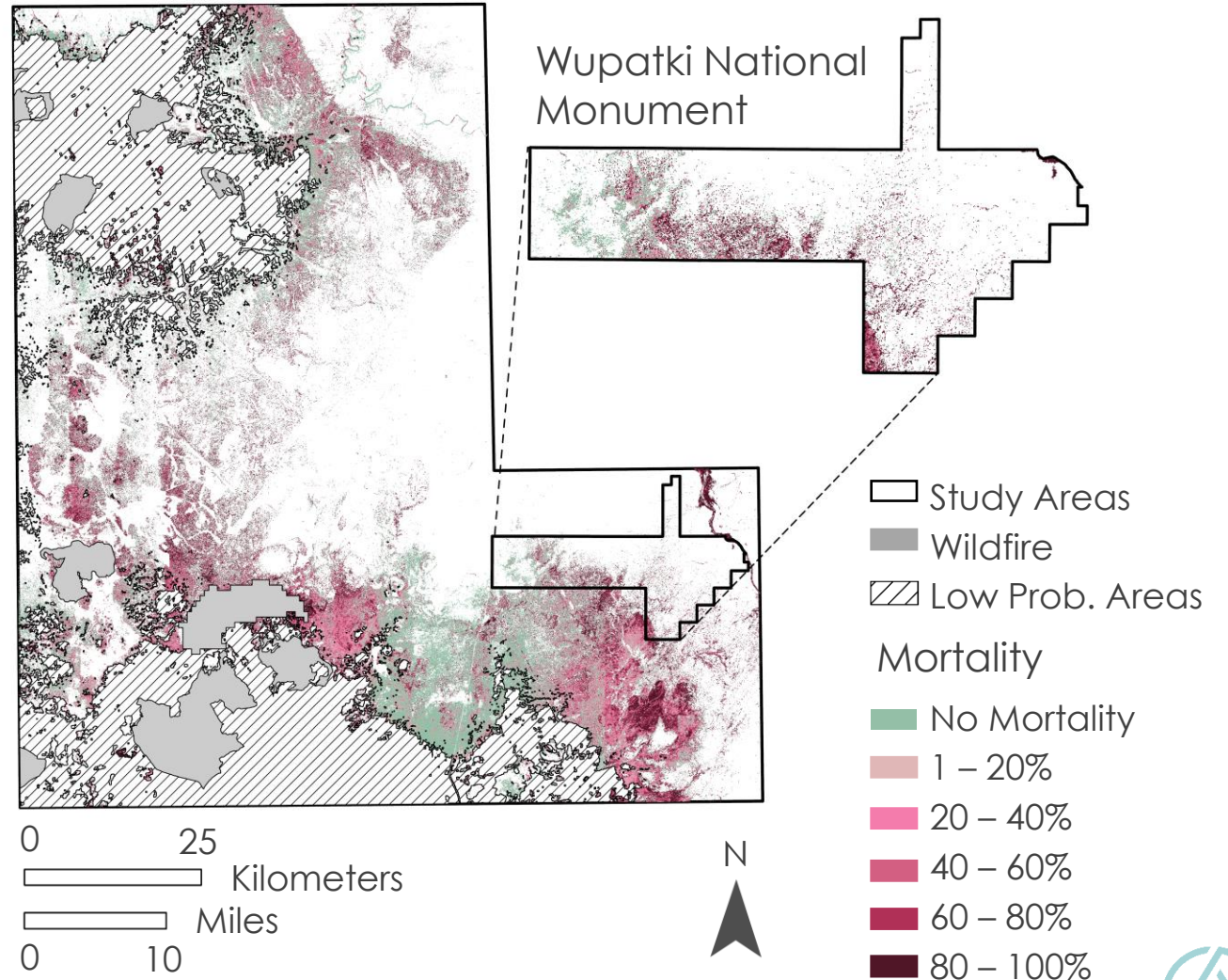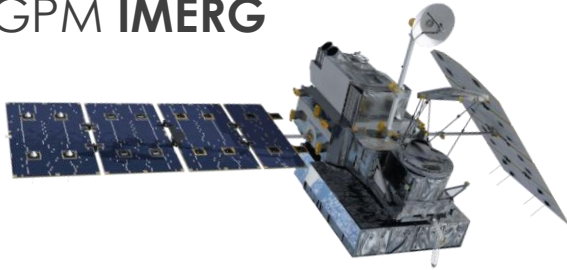*Areas excluding burn areas and mixed pinyon-juniper ponderosa forests

Wupatki National Monument
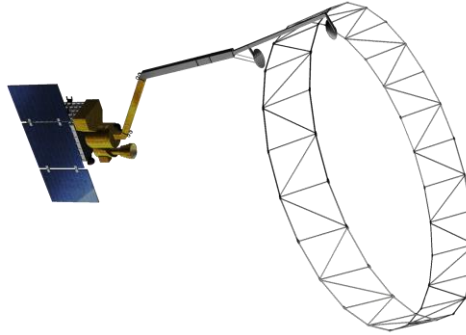
Study Areas
Wildfire
Low Prob. Areas

Mortality
No Mortality
1 – 20%
20 – 40%
40 – 60%
60 – 80%
80 – 100%

0   25
Kilometers
Miles
0   10

N

Image Credit: DEVELOP Team

METHODOLOGY: NASA SATELLITES & SENSORS

SMAP

GPM **IMERG**
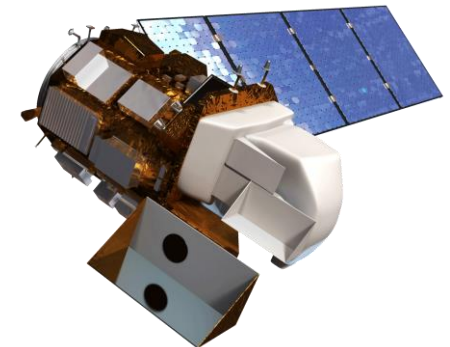
Terra **MODIS**
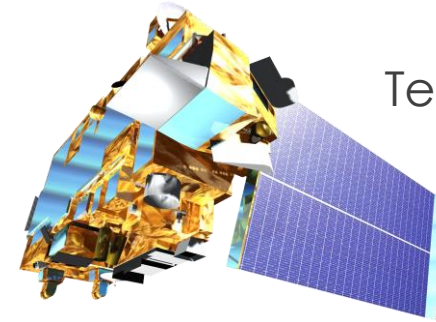
SRTM

Landsat 8 **OLI** & **TIRS**

Image Credit: NASA

METHODOLOGY: ENVIRONMENTAL VARIABLES
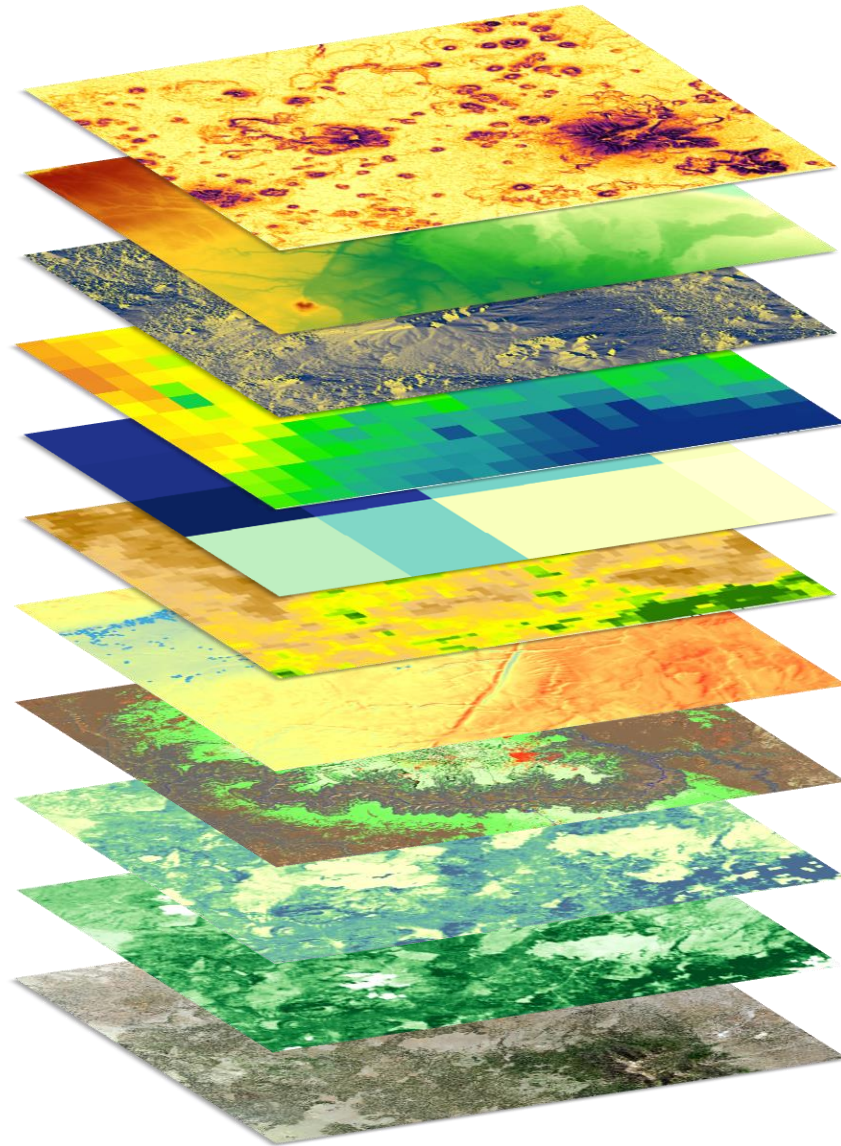
Slope ⎤
Elevation ⎬— Topography
Aspect ⎦
Precipitation
Soil Moisture
Evapotranspiration
Land Surface Temperature
LANDFIRE
Normalized Difference Moisture Index
Normalized Difference Vegetation Index
NAIP Aerial Reflectance Data

RESULTS: ENVIRONMENTAL VARIABLES

▸ **Precipitation** and **soil moisture** levels showed significant downward trend from 2015 to 2021

Rho in Wupatki NM:

▸ **Elevation** = -0. 37

▸ **Soil moisture** = 0. 39*

▸ **Land surface temp** = 0. 38*

*2020 – 2021 Mean Data Run

Mean Monthly Precipitation in Study Area, 2015 – 2021

p-value = .026

Mean Monthly Soil Moisture in Study area, 2015 – 2021
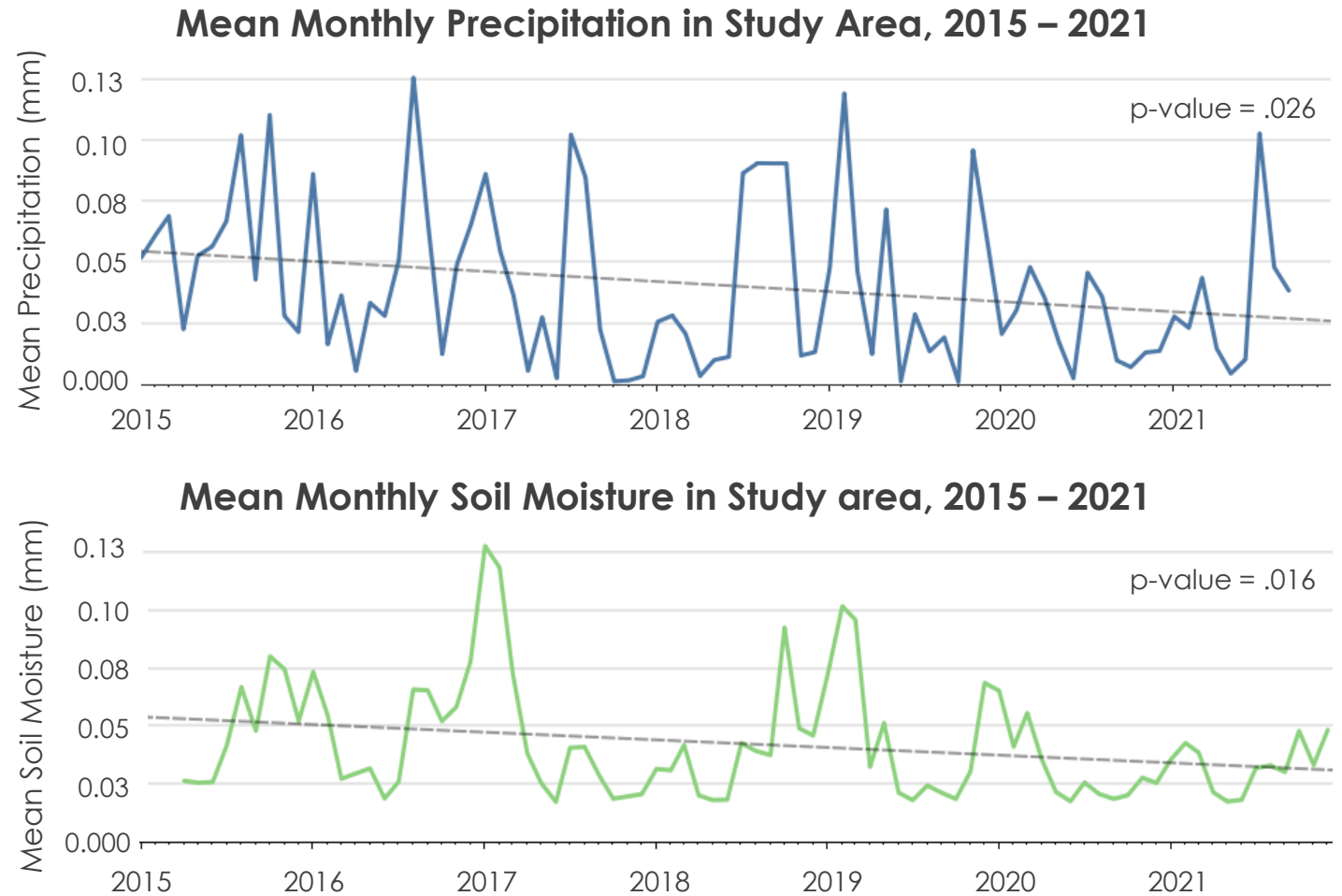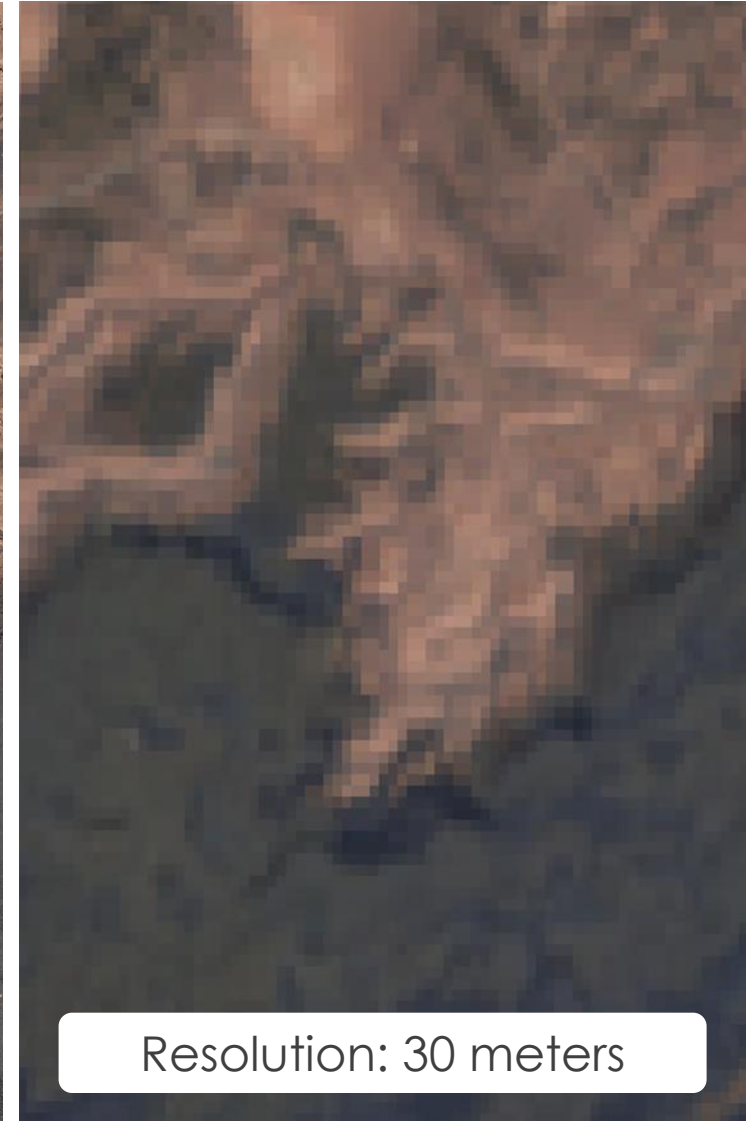
p-value = .016

Image Credit: DEVELOP Team

ERRORS & UNCERTAINTIES

▸ Error associated with unsupervised classification of pinyon-juniper stands

▸ Coarse resolution of some data products

▸ Other contributing variables not considered

Resolution: 0.6 meters

Resolution: 30 meters

Image Credit: DEVELOP Team

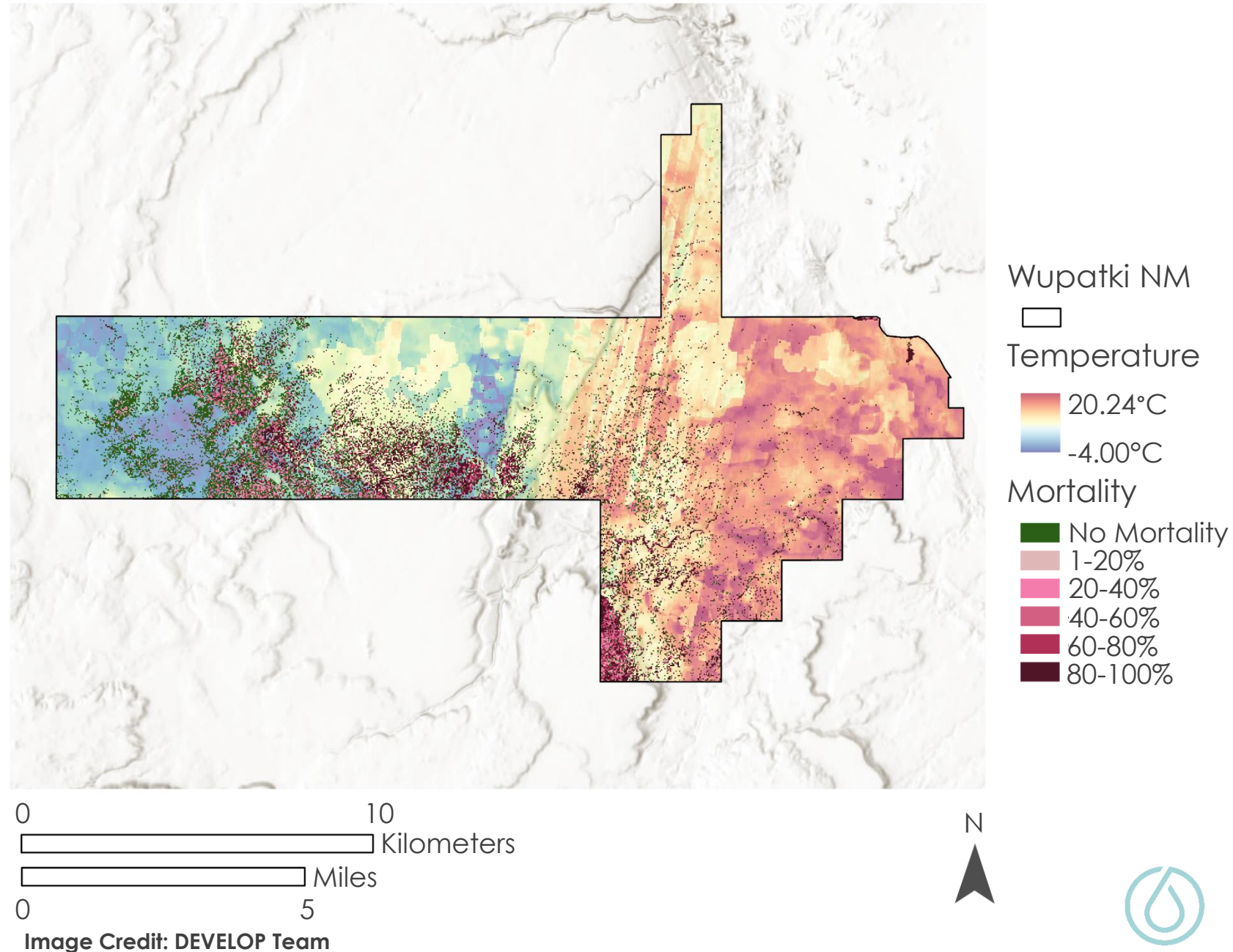# CONCLUSIONS

▸ NAIP imagery can be used to **accurately map mortality**

▸ High mortality percentages **corroborate partner observations** on the ground

▸ **No high correlations** with environmental variables and mortality

Wupatki NM

Temperature

20.24°C

-4.00°C

Mortality

No Mortality
1-20%
20-40%
40-60%
60-80%
80-100%

0   10
Kilometers

0   5
Miles

N

Image Credit: DEVELOP Team

FUTURE WORK

Increase the **accuracy** of unsupervised classification

Extend the **study period** to include previous years of drought

Yearly time series for mortality classifications

Image Credit: DEVELOP Team (left), Mark Szydlo (center), DEVELOP Team (right)

ACKNOWLEDGEMENTS

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APPENDIX

Accuracy Assessment Data

Assessment	# of Random Points	Method	# of Combined Classes	Accuracy	Kappa	Error	95% Confidence Interval
2015 Vegetation Classification	240	Equalized Stratified Random	4 - Pinyon-Juniper, Bare Earth, Shrubs, Shadow	82%	0.69	0.18	82% +/- 4.9
2021 Vegetation Classification	240	Equalized Stratified Random	4 - Pinyon-Juniper, Bare Earth, Shrubs, Shadow	73%	0.65	0.27	73% +/- 5.6
Mortality in High Confidence Areas	240	Equalized Stratified Random	2 - Mortality, Not Mortality	89%	0.78	0.11	89% +/- 4.0

APPENDIX

Environmental Variables

Platform & Sensor	Parameters	Use
Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	Land Surface Temperature, NDMI, NDVI	Land surface temperature, NDMI, and NDVI were used to evaluate their potential effects on pinyon-juniper mortality.
Soil Moisture Active Passive (SMAP)	Soil Moisture	SMAP was used to assess soil moisture over time in the region.
Global Precipitation Measurement (GPM) Integrated Multi-satellite Retrievals for Global Precipitation Measurement (IMERG)	Precipitation	Precipitation accumulation data, derived from algorithms to predict interpolated values, were used to assess precipitation over time.
Shuttle Radar Topography Mission (SRTM)	Elevation, Slope, and Aspect	Elevation, slope, and aspect were used to map topographic characteristics of the landscape.
Terra Moderate Resolution Imaging Spectroradiometer (MODIS)	Evapotranspiration, Burn Boundary (2021)	Terra MODIS was used to assess evapotranspiration over time and relate it with pinyon-juniper mortality.

APPENDIX

Time Series p-Values, 2015 – 2021

Variable	R^2	p-Value
Soil Moisture	0.071	0.016
Evapotranspiration	0.006	0.478
Precipitation	0.061	0.026
Land Surface Temperature	0.006	0.501
NDMI	0.007	0.454
NDVI	0.002	0.687

APPENDIX

		Spearman's Correlation	High Prob. Areas		Wupatki	
Date	**Variable**	**Rho**	**P-Value**	**Rho**	**P-Value**
No Date	Aspect	-0.01	0.4364	0.03	0.617
No Date	Elevation	-0.11	2.20E-16	**-0.37**	**3.75E-10**
No Date	Slope	-0.04	0.004554	-0.10	0.1215
No Date	Stand Density	0.02	0.1107	-0.03	0.6201
April 2019 - May 2021 Mean	Soil Moisture	0.04	1.95E-03	**0.35**	**4.66E-09**
April 2019 - May 2021 Mean	Evapotranspiration	-0.04	3.06E-03	-0.30	5.40E-06
April 2019 - May 2021 Mean	Precipitation	-0.03	0.01367	-0.14	0.02766
April 2019 - May 2021 Mean	Land Surface Temperature	0.12	2.20E-16	**0.35**	**4.94E-09**
April 2019 - May 2021 Mean	NDMI	-0.03	0.04881	0.19	0.001925
April 2019 - May 2021 Mean	NDVI	-0.12	2.20E-16	-0.07	0.2665
April 2020 - May 2021 Mean	Soil Moisture	0.05	4.32E-05	**0.39**	**1.01E-10**
April 2020 - May 2021 Mean	Evapotranspiration	-0.06	6.14E-05	-0.21	1.13E-03
April 2020 - May 2021 Mean	Precipitation	-0.06	5.78E-06	-0.20	0.001153
April 2020 - May 2021 Mean	Land Surface Temperature	0.12	2.20E-16	**0.38**	**3.21E-10**
April 2020 - May 2021 Mean	NDMI	0.00	0.7104	0.19	0.002817
April 2020 - May 2021 Mean	NDVI	-0.16	2.20E-16	-0.14	0.02352
April 2015 - May 2021 Difference	Soil Moisture	0.12	2.20E-16	**0.39**	**6.79E-11**
April 2015 - May 2021 Difference	Evapotranspiration	-0.02	9.25E-02	-0.10	2.18E-01
April 2015 - May 2021 Difference	Precipitation	-0.01	0.3516	-0.20	0.00121
April 2015 - May 2021 Difference	Land Surface Temperature	0.16	2.20E-16	0.33	3.15E-08
April 2015 - May 2021 Difference	NDMI	-0.10	0.000000	-0.23	0.000128
April 2015 - May 2021 Difference	NDVI	-0.05	0.000031	-0.06	0.304400